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Development and Validation of Integrated Behaviour Model (IBM) Instruments Through Confirmatory Factor Analysis (CFA) in *Plasmodium knowlesi* Malaria Behavioural Change

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ABSTRACT

Plasmodium knowlesi (*P. knowlesi*) malaria remains a significant public health challenge in Southeast Asia, particularly in Malaysia. Despite various preventive strategies, the rise in zoonotic malaria cases highlights the need for behaviourally focused interventions. This study aims to develop and validate a reliable instrument based on the Integrated Behaviour Model (IBM) to measure *P. knowlesi* malaria prevention behaviours among at-risk communities. A cross-sectional study was conducted in Hulu Selangor using a two-phase approach. Phase 1 involved qualitative elicitation interviews to explore attitudes, norms and perceived control toward five prevention behaviours: taking prophylaxis, wearing long sleeves and long pants, using insect repellent, using bed nets and using mosquito coils. These findings informed the development of a structured instrument. In Phase 2, confirmatory factor analysis (CFA) was applied to assess the validity and reliability of the instrument, using responses from 277 respondents. The CFA results showed that the developed instruments have achieved acceptable model fit, although some constructs exhibited reliability and validity concerns particularly attitude, subjective norm, and environmental constraint. The prevention behaviour items that showed the highest model fit among the five prevention behaviour items were wearing long sleeves and long pants and the lowest model fit was using insect repellent. This study provides a validated IBM based tool to assess *P. knowlesi* malaria prevention behaviours, contributing to more targeted intervention strategies. Future research should expand geographic coverage and use longitudinal methods to assess behavioural change over time.

Keywords: *Integrated behaviour model (IBM), knowlesi malaria, behavioural change, confirmatory factor analysis (CFA), instrument development and validation.*

INTRODUCTION

Plasmodium knowlesi (*P. knowlesi*) malaria is a major contributor to malaria cases in Southeast Asia, especially in Malaysia (Scott, 2020). It’s a zoonotic disease, and humans can be infected when they enter the host (long-tailed macaque) habitat and the vector (anopheles mosquito) in the forest.

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The geographical factors that aid the infection of *P. knowlesi* malaria in at-risk areas have been known to be the presence of hosts, humans, forest areas and farms (Naserrudin et al., 2022b). Communities living around these areas are at risk of getting infected with *P. knowlesi* malaria while indulging in outdoor activities such as farming, hunting in the evenings and walking at night (Brown et al., 2020) because likeliness of being bitten by mosquitoes increases after dusk (Chua et al., 2019). High-risk work and hobbies that include fishing and hunting are one of the main risk factors for the high rate of *P. knowlesi* malaria infection among these communities.

Apart from that, agricultural activities and deforestation result in changes in human settlement, and thus, they also disturb host and vector habitats. The study by Chin et al. (2020) showed that in 2018, more than 50% of *P. knowlesi* malaria cases in Malaysia were linked to forestry and agricultural activities, with significant numbers of cases associated with forest-related activities. Thus, men working in agricultural areas have the highest risk of *P. knowlesi* malaria infection (Grigg et al., 2017; Herdiana et al., 2016). In addition, industries including forestry, agriculture, and hunting have been identified as risk factors for *P. knowlesi* malaria infection (Grigg et al., 2017; Fornace et al., 2018).

Generally, many preventive measures have been used to protect from mosquito bites or to kill mosquitoes in the surrounding areas. Among the preventive measures that are commonly used are the long-lasting insecticide-treated Nets (LLINs), indoor residual spraying (IRS), using mosquito coils, insecticide sprays, taking prophylaxis, as well as individual preventive habits such as wearing long shirts and pants as well as local methods such as burning leaves and garbage to produce smoke (Ntuku et al., 2017; N'Dri et al., 2020; Cote et al., 2021; Nalinya et al., 2022; Damien et al., 2023).

However, studies found that many of these preventive initiatives did not reach an optimal level of effectiveness due to the challenges of the individual's knowledge of preventive measures and risk factors that influence infection. For example, a study conducted by Ntuku et al. (2017) showed that although LLINs are distributed free of charge in some risk areas, in some areas, it requires the head of the family or the representative of the householder to obtain LLINs from the distribution channel. The challenge here is that these individuals who receive LLINs, representing their families, lack knowledge on how to use and maintain LLINs consistently (Ntuku et al., 2017). This makes it difficult for successful eradication and prevention in these areas. Recently, the Malaysian National Malaria Elimination Strategic Plan 2011-2020 has succeeded in reducing the number of cases of human malaria (Vector Borne Disease Section, 2010). Nevertheless, zoonotic malaria cases have continued to rise and is becoming a major challenge in the public health agenda despite the many efforts being made (Rahim et al., 2020). The increasing threat of this zoonotic infection may also be influenced by the parasite's ability to adapt and improve in immunity over time, making existing methods ineffective, thus affecting malaria elimination goals in some regions (WHO, 2017).

Despite various preventive strategies, existing behavioural interventions often fall short due to insufficient contextual understanding. There is a lack of validated tools that assess behavioural determinants among at-risk populations. Hence, this study fills a gap by developing and validating an IBM-based instrument tailored to P. knowlesi malaria prevention. This effort is significant as it aligns with national goals to eliminate malaria and adresses behavioural nuances often overlooked in vector control programs.

LITERATURE REVIEW

The Integrated Behaviour Model (IBM) is a comprehensive framework that synthesizes constructs from major health behaviour theories, including the Theory of Reasoned Action, the Theory of Planned Behaviour, and Social Cognitive Theory (Fishbein et al., 2001). IBM emphasizes constructs such as attitudes, perceived norms, personal agency, habit, salience, and environmental constraints to explain and predict behavioural intentions and actions.

IBM has been widely applied in examining behaviours such as a study by Storey et al. (2018) showed that an understanding of individual and community knowledge, attitudes, environmental factors, and facilitators has provided vital information for improving human malaria prevention efforts. Furthermore, a recent study has recommended to integrate the understanding of human behaviour and its social environment to influence future behaviour change efforts to control zoonotic malaria in these at-risk areas (Naserrudin et al., 2022b).

P. knowlesi malaria infection prevention efforts need to account for the understanding of human behaviour, exploration of the social context and challenges and include community participation to maximally leverage efforts and be culturally appropriate (Naserrudin et al., 2022a). Lee et al. (2022) in their study stated that an accurate identification of potential risk factors associated with the transmission of *P. knowlesi* malaria infection is essential for disease intervention and prevention.

Therefore, this study is aimed at developing an IBM-based instrument that could assess the factors that influence *P. knowlesi* malaria prevention behaviours among at-risk communities and to test its reliability and validity. This instrument will help future studies to conduct more detailed and comprehensive research using IBM.

METHODOLOGY

This study was conducted as a cross-sectional study involving two phases. The first phase uses qualitative research methods to explore the subject's understanding of attitudes, personal agencies, subjective norms and risk factors that influence them towards *P. knowlesi* malaria prevention measures. The findings from in-depth interviews were used in developing the questionnaire involving IBM constructs. It was then face validated by the Public Health Specialists to ensure the content validity of the questionnaire. The second phase is a quantitative study to develop and validate the instrument of the at-risk *P. knowlesi* malaria community in Hulu Selangor.

Phase 1: Elicitation Study (Qualitative)

For the qualitative study, an elicitation interview was conducted upon the use of a formative study approach. According to the statistics retrieved from the Regional Health Office (PKD) in 2018, the states with the highest number of *P. knowlesi* malaria cases are Perak (175 cases), Pahang (119 cases), Kelantan (113 cases), Johor (42 cases) and followed by Selangor (45 cases). A total of three states, from the top five states with *P. knowlesi* malaria cases mentioned earlier, were randomly selected to conduct an in-depth interview among 17 individuals who had or had not been infected with *P. knowlesi* malaria. The sample consisted of 17 informants selected using purposive sampling, ensuring representation from individuals both with and without infection experience. The inclusion criteria of the informants are individuals aged 18 and over who were Malaysian citizens. The districts and states chosen were Kelantan (Gua Musang), Pahang (Kuala Lipis), and Johor (Kota Tinggi), and Hulu Selangor was chosen for a pilot study to test the development of the instrument.

During the interview session, the informants were requested to provide the following information:
1. Positive or negative feelings about prevention behaviour
2. Positive or negative outcomes of prevention behaviour
3. Individuals or groups who encourage or oppose prevention behaviour
4. Geographical factors and other obstacles affecting prevention behaviour

Table 1 shows the list of questions related to IBM variables toward *P. knowlesi* malaria prevention behaviours. These questions were adopted and adapted from Montano and Kasprzyk (2008).

Table 1: Lists of interview questions related to IBM constructs toward prevention behaviours

Constructs	Dimensions	Questions
Feelings about behaviour	Experiential Attitude	1. How do you feel about the idea of (prevention behaviour)? 2. What do you like or dislike about (prevention behaviour)?
Behavioural beliefs	Instrumental Attitude	1. What are the advantages of you doing (prevention behaviour)? 2. What are the disadvantages of you doing (prevention behaviour)? 3. What are the benefits that might result from doing (prevention behaviour)? 4. What are the negative effects that might result from performing (prevention behaviour)?
Normative beliefs – others' expectations	Injunctive Norm	1. Who would expect you to do (prevention behaviour)? 2. Who would not expect you to perform (prevention behaviour)?
Normative beliefs – others' behaviour	Descriptive Norm	1. Who would support you're doing (prevention behaviour)? 2. Who would be against you're doing (prevention behaviour)?
Control beliefs	Perceived Control	1. What things/factors/circumstances will make it easy for you to do (prevention behaviour)? 2. What things /factors/circumstances make it hard for you to do (prevention behaviour)?
Efficacy beliefs	Self-efficacy	1. If you want to do (prevention behaviour), how certain are you that you can do it correctly? 2. What kinds of things would help you overcome any barriers to doing (prevention behaviour)?

The informants involved in this phase were individuals aged 18 and over who were Malaysian citizens. This interview was conducted from June to August 2019. The first-phase results helped researchers to develop suitable items for IBM instruments based on the outcome of the interviews. The results of the first phase study revealed that there were five primary prevention behaviour suitable for *P. knowlesi* malaria behaviour change interventions: i) use of prophylaxis, ii) wearing long sleeve clothing and long pants, iii) using insect repellent, iv) using a bed net while sleeping and v) using mosquito coil (Azlan et al., 2023).

Phase 2: Instrument Development and Validation (Quantitative)

The second phase of this study involved a quantitative method, the confirmatory factor analysis (CFA), to test the validity of the instrument. The instrument has been distributed to

277 respondents in Hulu Selangor. According to statistics (2018) by PKD, the state of Selangor has recorded a total of 45 cases of *P. knowlesi* malaria, and Hulu Selangor was the district with the highest number of cases, with 31 cases. The number of samples in this study uses a suggestion by Gable & Wolf (2012), where the size of the sample represents six to ten times the number of instrument items. The number of samples in this research is seven times the number of 39 items of the instrument, which totals up to 277 respondents using the non-probability sampling techniques. The criteria for respondents for this study were as follows: (i) age 18 years or older, (ii) Malaysian citizens and (iii) individuals who receive health services and treatment from healthcare workers. The study was conducted from February to March 2020.

a. Research Instrument

Researchers developed items for each IBM construct through literature studies and the results from phase one of the study. For all IBM constructs, items were evaluated on a five-point Likert scale from Very Disagree (1) to Very Agree (5). The prevention behaviour was measured using six constructs in IBM, namely: attitude, personal agency, subjective norm, salience, habit and environmental constraints. The instrument consisted of three sections: Section A revolved around the socio-demographics of respondents; Section B was related to environmental, cultural, host-vector, control and prevention factors; and Section C consisted of items with prevention behaviour, prevention knowledge and health literacy levels. Refer to Table 2 for the list of items used in the instrument based on the literature and findings from Phase 1.

Table 2: IBM constructs and items used for the instrument

Constructs	Dimensions	Items	Sources
Attitude	Experiential	1. I feel that this prevention behaviour is necessary. 2. I feel that this prevention behaviour is effective. 3. I'm comfortable using this prevention behaviour. 4. I love using this prevention behaviour. 5. I'm worried about using this prevention behaviour.	Wan et al. (2017) Dai et al. (2017)
	Instrumental	6. This prevention behaviour will reduce malaria infection. 7. This prevention behaviour has a side effect on me. 8. This prevention behaviour is hard for me to do.	
Subjective Norms	Injunctive	9. The Ministry of Health expects me to do this prevention behaviour. 10. Family members feel I need to do this prevention behaviour. 11. People around me feel I need to do this prevention behaviour.	Lakerveld et al. (2011) Brattabø et al. (2019)
	Descriptive	12. The media (television, newspapers, posters, social media) have influenced me to do this prevention behaviour. 13. The Ministry of Health has influenced me to do this prevention behaviour. 14. People around me have influenced me to do this prevention behaviour. 15. My friends have influenced me to do this prevention behaviour.	Brattabø et al. (2019)

Personal Agency	Perceived Control	16. I'm doing this prevention behaviour because it's easy to use. 17. I'm doing this prevention behaviour because it's easy to get. 18. I did this prevention behaviour because of the low cost. 19. I can only do this prevention behaviour in certain situations.	Lakerveld et al. (2011) Dai et al. (2017)
	Self-efficacy	20. I'm sure I've used prevention behaviour correctly. 21. I'm not sure if I use/do this prevention behaviour correctly. 22. I'm able to do this prevention behaviour when I need it. 23. I believe this prevention behaviour can reduce the risk of malaria infection in monkeys.	Brattabø et al. (2019)
Salience		25. This prevention behaviour is important to me to reduce the risk of monkey malaria infection. 26. I dare take the risk of doing this prevention behaviour. 27. I'd be infected with monkey malaria if I took easy on this prevention behaviour.	Pope at al. (2020)
Habit		28. This prevention behaviour has become part of my routine or practice. 29. I do this prevention behaviour without being forced by anyone. 30. I'm doing this prevention behaviour not only just to avoid monkey malaria infection.	Lilje & Mosler (2018)
Environmental Constraints		31. I have limited time to do this prevention behaviour. 32. Weather factors prevented me from performing this prevention behaviour. 33. I can't do this prevention behaviour because of my health condition. 34. I'm worried about public acceptance when doing this prevention behaviour. 35. Equipment for this method of prevention is available (purchase, supply) in my area/location. 36. The equipment to perform this prevention behaviour is expensive.	Lilje & Mosler (2018)

RESULTS AND DISCUSSION

A total of 287 respondents responded to the survey, of which 10 of them (3.48%) were removed because the respondents were non-citizens. Hence, data from 277 respondents were analyzed. Table 3 below shows the demographic and background information of respondents.

Table 3: Respondents' demographics (N=277)

Variables	Number (N)	Percentage (%)
Gender		
Male	110	39.7
Female	167	60.3

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Age		
18-24 years	26	9.4
25-31 years	71	25.5
32-38 years	60	21.6
39-45 years	34	11.9
46-52 years	23	8.2
53-59 years	27	9.7
> 60 years	36	13.2
Race		
Malay	226	81.6
Chinese	2	0.7
Indian	39	14.1
Indigenous People/Orang Asli	5	1.8
Iban	2	0.7
Bidayuh	2	0.7
Dusun	1	0.4
Place		
Kg. Fajar, Sg. Tengi	16	5.8
Kg. Soeharto	29	10.5
Kalumpang Health Clinic	78	28.2
Rasa Health Clinic	49	17.7
Serendah Health Clinic	93	33.6
Ulu Yam Bharu Health Clinic	12	4.3

Gender wise, almost half the respondents (60.3%) were females, and the remaining were males (39.7%). The average age of the respondents was 39.6 years while the age category that had the most number of participants was from age range 25 to 31 years followed by the age range of 32 to 38 years. The majority of respondents were Malays (81.9%), followed by Indians (13.7%) and Indigenous People/Orang Asli (1.8%). The respondents represented all 14 districts in Hulu Selangor and respondents from the Serendah sub-district (33.2%) contributed the most in this survey.

CFA Procedures

In the first phase, the items in the instrument developed were rated by five panel experts (three experts from the PKD Vector Unit; and two experts from the Ministry of Health, Malaysia) to establish face validity and content validity. Next, confirmatory factor analysis (CFA) was performed with the help of the AMOS version 23 software to test the instrument's construct validity, already stated below. The measurement model was based on the goodness of fit criteria, which test the compatibility of the theoretical model with empirical data.

CFA was employed using the maximum likelihood method because the data were normally distributed. All six constructs contained 39 items in total; evaluating attitude (9 items), subjective norms (7 items), personal agency (8 items), salience (3 items), habit (3 items), and environmental constraint (9 items) for each prevention behaviour. Items were deemed construct valid if items significantly loaded on the scale it was expected, and model fit indices were appropriate (Comparative Fit Index (CFI ≥ 0.95), Tucker–Lewis Index (TLI ≥ 0.95), and Root Mean Square Error of Approximation (RMSEA ≤ 0.08) (24).

The construct validity of the instrument was assessed using convergent validity, composite reliability, and discriminant validity (Yusof et al., 2017). Convergent validity is evaluated using the Average Variance Extracted (AVE) value to explain the ability of the construct to share the item or the accuracy of the item used to describe the construct (Cheung et al., 2024). According to Cheung et al. (2024) and Ab Hamid et al. (2017), the AVE value ≥ 0.5 is considered acceptable. Composite reliability (CR) measures the internal consistency of a set of indicators reflecting a single construct, where a CR value ≥ 0.7 shows a good reliability (Baistaman et al., 2020; Ibrahim et al., 2017). Discriminant validity evaluates whether constructs that are supposed to be distinct are different from one another (Cheung et al., 2024). Discriminant validity can be assessed using several methods, one of which is the Fornell-Larcker criterion, which suggests that the square root of the AVE for each construct should be greater than the correlations between that construct and other constructs (Cheung et. al, 2024). Additionally, the Heterotrait-Monotrait (HTMT) ratio has emerged as a more stringent criterion, with values below 0.85 indicating acceptable discriminant validity (Cheung et al., 2024; Ab Hamid et al., 2017). The summary of validity and reliability requirements is presented in Table 4 below.

Table 4: Type of validity and reliability and their level of acceptance

Validity	Name of Category	Threshold	Sources
Construct Validity	Fitness Indexes	RMSEA < 0.08 (Absolute Fit) CFI & TLI > 0.9 (Incremental Fit) Chisq/df <3.0 (Parsimonious Fit)	Awang et al. (2015), Awang et al. (2018)
Convergent Validity	AVE	AVE > 0.5	
Discriminant Validity	Discriminant Validity Index Summary		
Composite Reliability	CR	CR > 0.6	

a. Convergent Validity

Table 5: AVE values for each construct across prevention behaviour

Prevention Behaviour	Attitude	Personal Agency	Subjective Norm	Salience	Habit	Environmental Constraint
Taking *prophylaxis* (PB1)	0.889	0.833	0.570	0.663	0.578	*0.450
Wearing long sleeves and pants (PB2)	*0.400	0.859	0.779	0.610	0.617	0.740
Using insect repellent (PB3)	*0.202	0.857	0.865	0.690	0.632	*0.359
Using bed net (PB4)	*0.304	0.646	0.623	0.564	0.682	0.591
Using mosquito coil (PB5)	1.102	0.829	*0.472	0.578	0.634	*0.411

* below the acceptable threshold

Based on Table 5, for the measurement of AVE, the value of attitude reported was below the acceptable threshold of 0.5 for both PB2 and PB4. PB3 had both attitude and environmental constraint constructs below the threshold level, while PB1 only had environmental constraints below the threshold level. PB5 was the only behaviour that had a subjective norm below the threshold level, along with environmental constraints seen in other prevention behaviours. Collectively, attitude was the only construct that was found mostly below the threshold level, followed by environmental constraint and subjective norm. The AVE value below 0.50 (acceptable threshold) indicates that the construct does not explain at least 50% of the variance in its indicators, suggesting a lack of convergent validity. Meanwhile, the value for the other constructs above the threshold value in all prevention behaviours effectively captured the variance in their indicators.

b. Composite Reliability

Table 6: CR values for each construct across prevention behaviour

Prevention Behaviour	Attitude	Personal Agency	Subjective Norm	Salience	Habit	Environmental Constraint
Taking *prophylaxis* (PB1)	*0.199	0.908	0.721	0.855	0.796	0.797
Wearing long sleeves and pants (PB2)	*0.527	0.924	0.866	0.757	0.828	0.849
Using insect repellent (PB3)	*0.080	0.923	0.912	0.870	0.836	0.788
Using bed net (PB4)	*0.431	0.783	0.767	0.795	0.864	0.809
Using mosquito coil (PB5)	1.076	0.907	*0.641	0.803	0.838	0.804

* below the acceptable threshold

As for the CR values in Table 6, the attitude construct was observed to be below the threshold level for PB1, PB2, PB3 and PB4. The subjective norm construct was the only contradicting construct that recorded a CR value less than the threshold level obtained from PB5. The CR value below the acceptable threshold of 0.70, indicates poor internal consistency among the indicators used to measure this construct. The CR values for other constructs indicate good internal consistency in all preventive behaviours.

c. Discriminant Validity

Table 7: Discriminant validity for each construct across prevention behaviour

Prevention Behaviour	Attitude	Personal Agency	Subjective Norm	Salience	Habit	Environmental Constraint
Taking *prophylaxis* (PB1)				Achieved		
Wearing long sleeves and pants (PB2)	*	*	Achieved	*	*	Achieved
Using insect repellent (PB3)	*	*	Achieved	*	*	Achieved
Using bed net (PB4)	*	*	Achieved	*	*	Achieved
Using mosquito coil (PB5)	Achieved	Achieved	Achieved	*	Achieved	Achieved

* below the acceptable threshold

The coefficient of correlation between the components is assessed and presented in Table 7. There were no concerns on discriminant validity for prevention behaviour of using prophylaxis (PB1) because the values above all meet the threshold of 0.85. However, for prevention behaviour of wearing long sleeves and pants (PB2), using insect repellent (PB3) and using bed nets (PB4), all three have discriminant validity concerns on four constructs, which are attitude, personal agency, salience and habit. The finding for using mosquito coil (PB5), the discriminant validity concern is observed only on the salience factor. Discriminant validity is considered low in the constructs above because the AVE's square root is less than one, and the absolute value of the correlations between the construct and prevention behaviour does not exceed 0.85 (Noor et al., 2015).

d. Construct Validity Model-Fit Through CFA

CFA analysis was carried out by measuring five prevention behaviours with 5 items on experiential attitude, 3 items on instrumental attitude, 3 items on injunctive norms, 4 items on descriptive norms, 4 items on perceived control, 4 items on self-efficacy, 3 items on salience, 3 items on habit and 9 items on environmental constraints. All items for each prevention behaviour have a loading factor value of at least (λ) > 0.3 which indicates an acceptable factorability which means that the item is valid and suitable for use (29, 30). It has been suggested that the measurement model achieve the construct validity when all the three model fitness indexes surpassed the required value as in the Table 4.

Based on Figure 1, the CFA results for taking prophylaxis showed a Comparative Fit Index (CFI) of 0.88, Tucker-Lewis Index (TLI) of 0.86, and Root Mean Square Error of Approximation (RMSEA) of 0.084. While the model achieved satisfactory fit indices, it had to remove 11 items to reach this level.

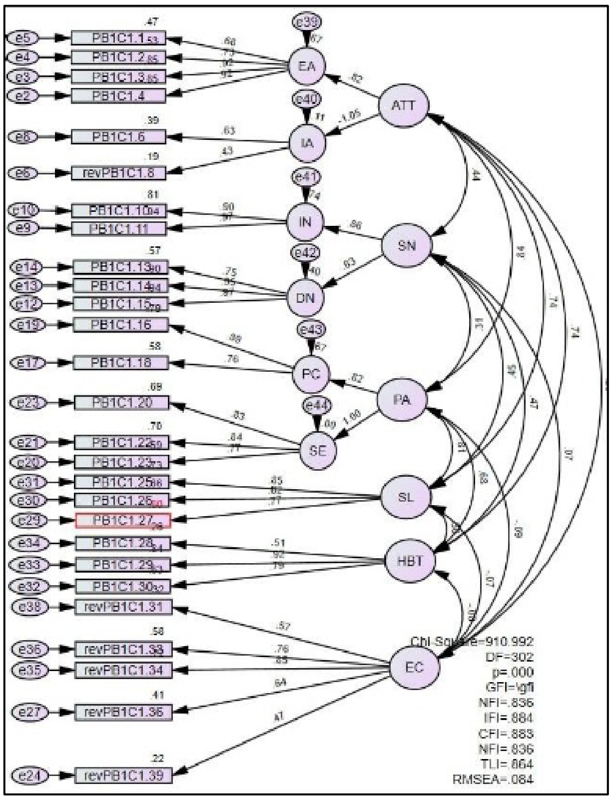

Figure 1: CFA results for instrument PB1

Figure 2 shows the CFA result for wearing long-sleeved clothing with a CFI of 0.90, TLI of 0.88, and RMSEA of 0.083. This model fit is commendable, but it required the removal of 15 items to achieve these indices. The items were largely removed from environmental constraints and experiential attitudes.

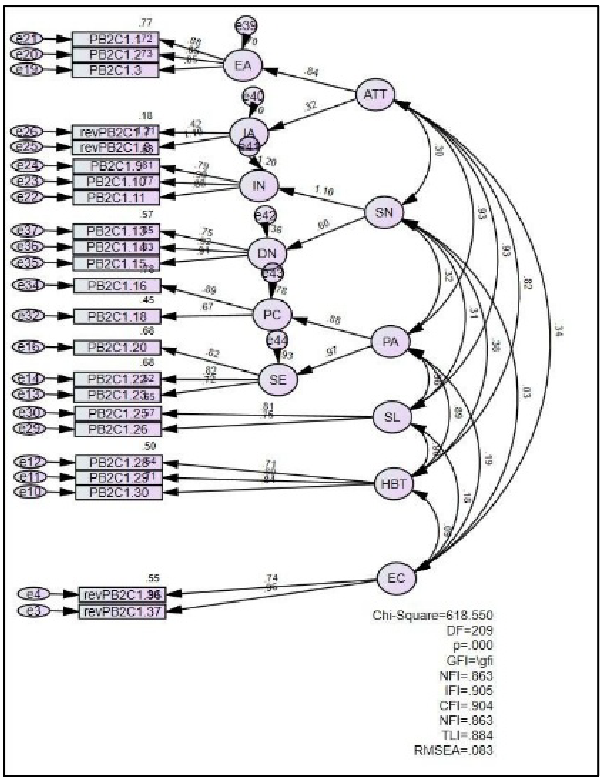

Figure 2: CFA results for instrument PB2

Figure 3 showed the CFA results for using insect repellent with a CFI of 0.80, TLI of 0.78, and RMSEA of 0.085. These indices indicate a poorer model fit compared to other prevention behaviours. Only one item was removed to achieve this fit.

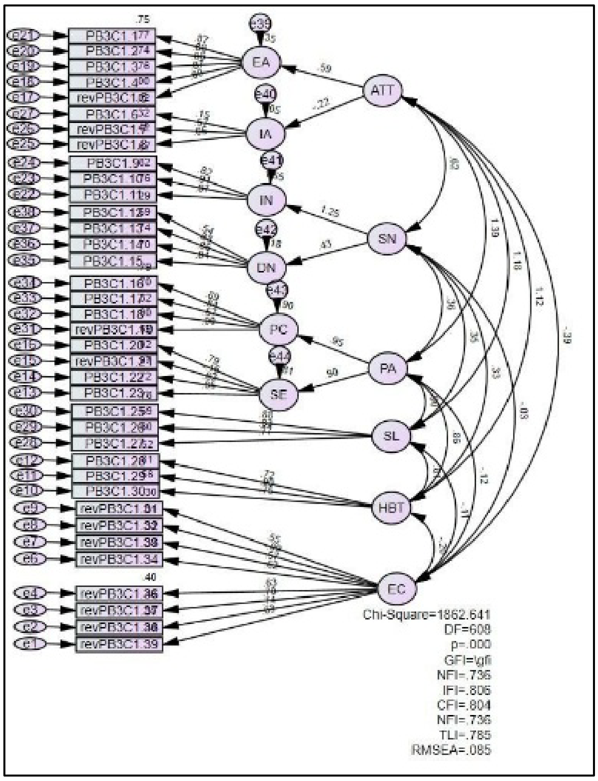

Figure 3: CFA results for instrument PB3

Figure 4 showed the CFA result for using a bed net with a CFI of 0.88, TLI of 0.86, and RMSEA of 0.085. Similar to PB1, 12 items were removed from this model to achieve acceptable fit indices, especially from the environmental constraints construct.

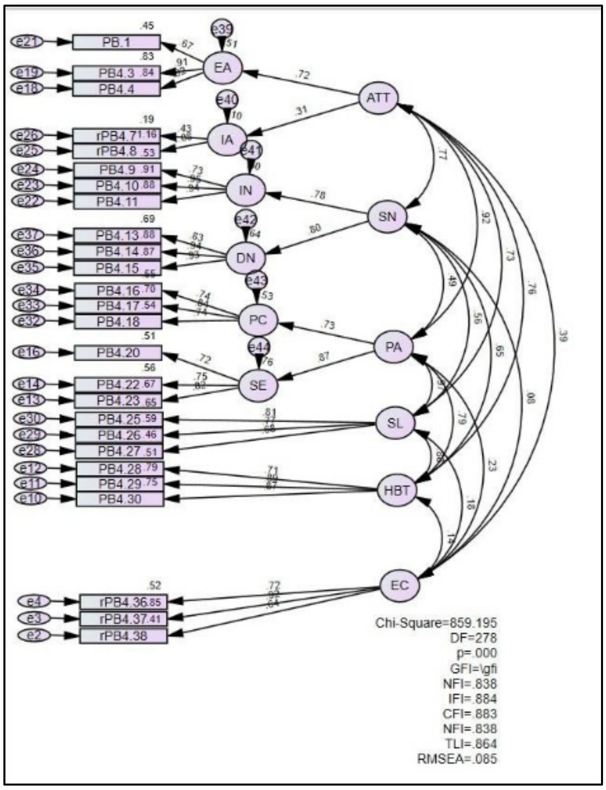

Figure 4: CFA results for instrument PB4

The CFA results for using mosquito coils are shown in Figure 5, a CFI of 0.86, TLI of 0.85, and RMSEA of 0.77, which are acceptable fit indices. However, the model required nine items to be removed to reach this fit and major concerns were from the subjective norm and environmental constraints constructs.

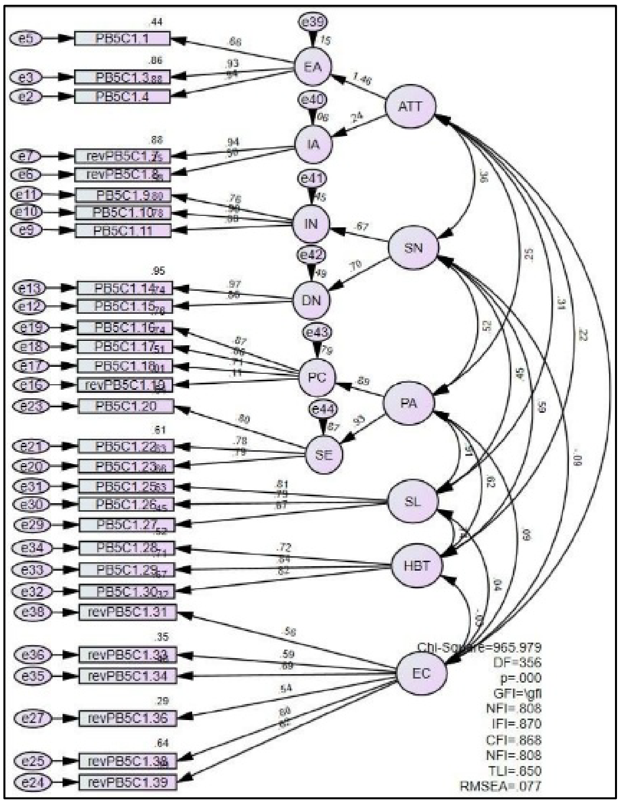

Figure 5: CFA results for instrument PB5

Instrument Reliability and Validity

Following the CFA analysis of the IBM instrument, the AVE score for the attitude construct was observed to be less than the threshold level for preventive behaviours PB2 which represents the behaviour of wearing long-sleeved clothing; PB3 represents the use of insect repellent and PB4 represents the preventive behaviour of using bed net while sleeping at night. This is similar to a study involving validation of an instrument for dengue infection in almost all constructs (Zamzuri et al., 2021). However, the instrument was still reported to be satisfactory as other measurements were above satisfactory (Zamzuri et al., 2021). This is because the behaviour of wearing long-sleeved clothing, using bed nets and mosquito coils may not have been perceived as suitable acts of preventing *P. knowlesi* malaria infection by these respondents.

As an example, using bed nets to prevent malaria mosquito bites may have been also considered a traditional method that is no longer preferred or used by the public, hence, may have been perceived as unsuitable for use by the respondents as a way of preventing *P. knowlesi* malaria. Poor outlook on the use of bed nets and the difficulty in fixing as well as inconsistency of usage may have been some of the factors of an unconvinced pool of respondents (Akello et al., 2022). People are more likely to have a positive perception and adaptation of a behaviour if it can produce positive impacts.

Another point to ponder is that, as most respondents are Malay Muslims, wearing long-sleeved clothing is part of their everyday norms. Hence, it can also be inferred that they practice the preventive measure without realizing it as a prevention behaviour against *P. knowlesi* malaria. So it can be concluded that there should be an intervention to increase the level of health literacy specifically of *P. knowlesi* malaria. This will enable the population to practice the prevention behaviours with conscience and awareness. Targeted holistic community engagement initiatives could be utilized to create awareness and promote positive practice of prevention behaviours as these methods are still proven to be effective (Barak et al., 2024).

On the other hand, AVE scores were above the threshold level for the attitude construct for preventive behaviours of using both the prophylaxis (PB1) and mosquito coil (PB2). Both these preventive behaviours were seen supportive in several other studies as well (Avicor et al., 2017; Hogarh et al., 2018; Ipa et al., 2020; Shuiabu et al., 2021). In this case, the benefits may have been experienced by the respondents, hence, the support for these prevention behaviours.

As for PB3, apart from the attitude construct, the environmental constraint construct was also recorded to be below threshold level. This is because the use of insect repellent may be limited by factors such as skin sensitivity, unpleasant odour, lack of awareness of its importance, or irregular availability and affordability in local markets, which might have discouraged consistent use among respondents. PB5 representing the usage of mosquito coil was the only behaviour that had subjective norm below threshold level along with the environmental constraint construct. This may be due to the perception that mosquito coils are a less formal or traditional method of prevention, often used out of convenience rather than as a consciously adopted health behaviour. Additionally, concerns about health risks from prolonged smoke inhalation might have influenced respondents to perceive weaker social support or approval, thus contributing to the lower subjective norm scores.

Collectively, attitude was the only construct that was found mostly below threshold level followed by environmental constraint and subjective norm. The AVE value of below 0.50 (acceptable threshold) indicates that the construct does not explain at least 50% of the variance in its indicators, suggesting a lack of convergent validity (Cheung et al., 2024). Meanwhile, the value for the other constructs above threshold value in all preventive behaviours effectively captured the variance in its indicators. Each construct was rated based on their current suitability and from these findings, some modifications can be made to the existing instrument for better suitability in future. High AVE values were also reported in similar studies validating instruments for evaluating knowledge, attitude and preventive behaviours of respondents towards malaria, respectively (Ismail et al., 2020, Jimam et al., 2019). The rating procedure was done by applying the dichotomous rating scale that eliminates the probability for chance agreement among raters (Marar et al., 2023). Hence, the measurement can be considered robust and allows direct feedback for improvement (Sangoseni et al., 2013).

As for the CR values, attitude construct was observed to be below threshold level for PB1, PB2, PB3 and PB4. The CR value of below the acceptable threshold of 0.70, indicates poor internal consistency with low shared variance among the indicators (Cheung et al., 2024). This shows that either of items do not measure the same construct and needs to be reconsidered. The same has been recorded in a different study on their attitude construct where some items were removed to achieve a better reliability score (Haji-Othman & Yusuff, 2022). This score of reliability was also obtained based on data from only three different districts in Malaysia and might produce discrete results when tested using different or a more varied data sets. This probability was also discussed in a Casemix study involving the healthcare system among five different hospitals in Malaysia (Mustafa et al., 2024). The subjective norm construct was the only contradicting construct that recorded a CR value less than threshold level obtained from PB5. The CR values for other constructs indicates good internal consistency in all preventive behaviours.

Discriminant Validity Value

Discriminant validity is crucial to determine whether the constructs being measured are truly distinct from one another. In this study, the Fornell-Larcker criterion and Heterotrait-Monotrait ratio (HTMT) were used to evaluate discriminant validity across the five prevention behaviours. A construct is considered to achieve discriminant validity if the square root of the AVE for each construct is greater than its correlation with other constructs, and HTMT values are below 0.85 (Cheung et al., 2024; Noor et al., 2015).

The results revealed that for the prevention behaviours of wearing long sleeves and pants (PB2), using insect repellent (PB3), and using bed net (PB4), several constructs namely attitude, personal agency, salience, and habit did not meet the required thresholds. These overlaps suggest that respondents might have perceived some of these constructs similarly across these behaviours. For example, personal agency and habit may intertwine when a behaviour becomes routine but is also perceived as within one's control, thus reducing their empirical distinction.

For PB5, which represents the use of mosquito coils, only the salience construct failed to meet the discriminant validity criteria. This suggests that respondents may not perceive mosquito coil usage as a highly significant or intentional prevention behaviour. Mosquito coils are often used passively or out of habit, without a strong cognitive or emotional investment, which may explain the blurred line between salience and other constructs like habit or attitude. Additionally, the informal and traditional nature of mosquito coil usage, often lacking explicit promotion by health authorities, may diminish its perceived salience in structured prevention strategies (Avicor et al., 2017).

Future modifications of the instrument should refine the items to improve discriminant validity. Redundant items with overlapping wording or meaning should be reviewed, and clearer distinctions between constructs should be maintained during item development. Conducting additional cognitive interviews with target populations could help identify whether certain constructs are conceptually misunderstood or perceived as interchangeable (Sangoseni et al., 2013). Furthermore, expanding the geographic and demographic scope of future studies may help to test the generalizability of these constructs across varied populations (Mustafa et al., 2024).

In summary, while discriminant validity was established for certain behaviours like taking *prophylaxis* (PB1), it was less robust for others. This underscores the need to refine the instrument to ensure conceptual clarity and empirical distinction between IBM constructs for each *P. knowlesi* malaria prevention behaviour.

Model Fit Through CFA

The CFA results for taking *prophylaxis* (PB1) achieved a satisfactory fit indices, however, 11 items had to be removed to establish this fit, mainly due to the environmental constraint construct. Environmental constraints such as limited access to healthcare services, medication availability and logistical challenges significantly impact individuals' ability to adhere to taking prophylaxis. A study in Cambodia highlighted that forest-goers faced barriers like side effects of antimalarials, economic implications and the complexities of their forest activities, which affected their uptake of prophylaxis (Jongdeepaisal et al., 2021). Similarly, in

Kenya, issues such as drug shortages in public health facilities and distance to healthcare centers were identified as major barriers to effective malaria treatment (Chuma et al., 2010; Jongdeepaisal et al., 2021). These environmental constraints not only hinder access to prophylactic measures but also influence individuals' perceptions and behaviours regarding malaria prevention. Understanding and addressing these barriers are crucial for improving adherence to malaria prophylaxis and, consequently, for the success of malaria prevention programs.

As for wearing long sleeves and pants (PB2), this model fit obtained was commendable, but it required the removal of 15 items to achieve these indices, particularly from environmental constraints and experiential attitudes. This is probably due to the fact that people and their environment have changed as items focused on geographical areas that are not very common anymore, hence, being unsuitable for respondents to answer. Changes in the environment is one of the factors that affect the reliability of a tool (Gay, 1980).

Using insect repellent (PB3) revealed the poorest model fit compared to other prevention behaviours. However, only one item was removed to achieve this fit implying that either the model is highly restrictive or the items do not adequately capture the complexity of the factors that affect this behaviour.

Next, for using a bed net (PB4), 12 items were removed from this model to achieve acceptable fit indices. The reliability issues within the attitude and other constructs suggest that this instrument may need to be revised to improve its ability to measure the nuances of attitudes toward using bed net. Humans constantly change due to the experiences they undergo in a certain period of time, hence, the measure of attitude construct for reliability can be challenged every few years (Taber, 2017).

Finally, the analysis for using mosquito coils (PB5) showed that an acceptable fit was achieved. Reliability concerns were around the subjective norm and environmental constraints constructs. Subjective norms may be less defined due to the informal and individualized nature of the practice. Unlike more communal prevention behaviours, such as the use of long-lasting insecticidal nets (LLINs), which are often promoted through public health campaigns and community programs, mosquito coils are typically used privately within households without broader community endorsement or discussion.

Research indicates that when malaria prevention behaviours are not publicly endorsed or commonly discussed within a community, individuals may lack clear perceptions of social expectations regarding those behaviours. For instance, a study in rural Uganda found that misperceptions about the prevalence of mosquito net use led to reduced personal usage, highlighting the importance of perceived social norms in influencing behaviour (Perkins et al., 2019). Similarly, the private nature of mosquito coil usage may result in ambiguous subjective norms, thereby affecting the reliability of this construct in measurement models.

For environmental factors, the availability and affordability of mosquito coils can vary significantly across different regions and socioeconomic groups. In some areas, it may be readily available and inexpensive, while in others, it may be scarce or costly, influencing usage patterns (Makungu et al., 2017). Perceptions of the effectiveness and safety of mosquito coils also can affect their usage. Some individuals may question the efficacy of mosquito coils in preventing malaria or express concerns about potential health risks associated with their smoke. These perceptions can act as barriers, limiting the consistent use of mosquito coils and complicating the assessment of environmental constraints in measurement models.

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Collectively, the removal of items from the environmental constraints and other constructs suggesting that these items may not be accurately represented (Taber, 2017). These findings indicate that these constructs may not adequately represent the contextual barriers and social effects impacting these prevention behaviours. It also raises concerns about the comprehensiveness of these constructs in capturing the barriers faced by individuals in adhering to these prevention behaviours.

Ultimately, the CFA analysis conducted shows that almost all constructs needed removal of items, where in hindsight, shortening the instrument can have positive effects on the study.

CONCLUSION

This study focuses on instrument development and validation of IBM instruments for assessing *P. knowlesi* malaria prevention behaviours among at-risk communities. Findings suggest that while model fit was generally acceptable, refinements are necessary to improve construct reliability and applicability. The validated instrument offers a foundational tool for future behavioural research and policy targeting vector-borne disease prevention.

The requirement for item removal across these five prevention behaviours indicates that further refinement is required to improve the measurement of attitudes, norms, and environmental constraints. These issues suggest the need for refinement in item wording and construct clarity. For example, the perception of informal prevention methods like mosquito coils or underutilized methods such as bed nets may affect construct interpretation and consistency (Avicor et al., 2017; Perkins et al., 2019).

Among the five prevention behaviours, wearing long sleeves and long pants (PB2) achieved the best model fit, potentially due to its routine incorporation into respondents' daily attire and cultural practices. Conversely, using insect repellent (PB3) yielded the poorest fit, indicating a need for further examination of the complexity and contextual relevance of the items representing this behaviour.

There are some suggestions for future studies where the validated IBM based instruments can serve as a foundational reference for developing similar behavioural instruments tailored to other vector-borne diseases or different cultural settings, especially in regions with comparable ecological and health system challenges. Additionally, future research should aim to expand the geographical coverage and sample size, incorporate mixed-method designs for deeper contextual understanding and apply advanced analytical techniques like structural equation modelling (SEM) for greater construct precision (Cheung et al., 2024; Sangoseni et al., 2013).

Future research should focus on expanding the item pool and testing the revised instruments to ensure a comprehensive assessment of *P. knowlesi* malaria prevention behaviours. This approach will ensure a more robust and adaptable instrument to inform targeted interventions and policymaking for zoonotic malaria control and other public health priorities.

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